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Interactive comment on "Changes to the tropical circulation in the mid-Pliocene and their implications for future climate" *by* Shawn Corvec and Christopher G. Fletcher

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article **General comments:**

We would like to thank reviewer 2 for the feedback and constructive criticism. Below we hope to address the comments made with the specific comment highlighted in blue and our response below in red:

Responses to comments from reviewer 2:

Rather then analogue I would prefer the time period referenced as a unique op-

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Discussion paper

portunity to better understand climate dynamics and behavior in a warmer world. The implications of this are obvious without having to engage in any complex discussion on what constitutes an analogue or not.

We have changed the sentence on page 3/line 35 to read: “As such, the mPWP provides a unique opportunity to improve our understanding of large scale climate dynamics in a warmer world.".

Please use mPWP throughout and not mpWP

We have changed all abbrevations of mid-Pliocene Warm Period to “mPWP".

I would also note that differences in orbital parameters in the mPWP overall were not "minor" from modern as the authors suggest. The Laskar orbital solution shows that across the âĹij300 Kyrs of the mPWP that there were very large changes in insolation at the TOA. Convention in previous model simulations for the mPWP was to use a modern orbit even those the evaluation data (SSTs and vegetation) would reflect a complex response to an amalgam of orbital forcing (due to its time average nature). This is why in PlioMIP Phase 2 they are focusing on a narrower time slice âĹij3.2 Ma where the orbital forcing represented by the SST responses, and given to the models themselves, is consistent.

End of second paragraph in “Data and Methods" section on page 4 re-written as:

“It has been suggested that using paleoclimate reconstructions over such a long period may not be appropriate, as shorter-term fluctuations in climate forced by changes in orbital parameters mean that proxy data may not be representative of conditions from the time period consistent with the boundary conditions (e.g., Salzmann et

al., 2013). Indeed, over the ∼300 Kyr mPWP, it has been shown that solar insolation exhibited very large fluctuations (Laskar et al., 2004). The next phase of the PlioMIP project, PlioMIP2, will mitigate against this issue by focusing on a narrower time period at 3.2 Ma, with consistent orbital and SST forcing."

"... in the introduction the authors should expand upon the aspects of tropical circulation response that models, when simulating future climate, are not consistent about."

The second last paragraph of the introduction as follows (split into 2 paragraphs) as: "The weakening of the meridional overturning circulation (HC) in response to climate change is less robust than the weakening of the WC. A poleward expansion of the descending branch of the HC in the wintertime northern hemisphere is considered the most robust projection for the future response, although the physical mechanisms for this are not well understood (Lu et al., 2007; Kang and Lu, 2012). Additionally, as the troposphere warms, the HC is expected to expand vertically as the tropopause height in the tropics increases, an effect which may already be apparent in observations (Santer et al., 2003). The CMIP5 models show fairly good agreement for a weakening of the Northern Hemisphere HC, with substantial disagreement over the sign of the response of the Southern Hemisphere cell (He and Soden, 2015; Ma and Xie, 2012; Vecchi and Soden, 2007). However, satellite observations and reanalysis data suggests that the HC has, in fact, strengthened rather than weakened since 1979 (Mitas and Clement, 2005; Liu et al., 2012). This apparent contradiction may be the result of poor model parameterization of clouds or convection (e.g., Mitas and Clement, 2006; Sohn et al., 2016) or due to natural variability. For example, internal fluctuations in the tropical and extratropical oceans, have effects on the tropical circulation in the short term that could be masking a longer term trend (Kosaka and Xie, 2013).

Part of the variability in HC strength could be explained by changes in merid-

ional SST gradients, which have been shown to weaken (strengthen) the HC if these gradients weaken (strengthen) (e.g., Seo et al., 2014; Levine and Schneider, 2010; Williamson et al., 2013; Gastineau et al., 2009; Kamae et al., 2011). The meridional SST gradient from the tropics to mid-latitudes is greatly reduced in the mPWP (e.g., Haywood et al., 2013; Dowsett et al., 1996; Dowsett and Robinson, 2009), which to leading order weakens the HC as shown in Kamae et al. (2011)." This reduced meridional SST gradient world can provide a test-bed for the climate models to better gauge the sensitivity of the HC to these boundary conditions.